INSTRUCTIONS SHEET – INBO 2016

The question paper is divided into Section A and Section B.

All answers should be **written in the answer sheet booklet only** which will be collected at the end of the examination.

The question paper need not be submitted to the examiner.

Section A

- Section A consists of 29 questions carrying 1 point each.
- All 29 questions are of multiple choice type, with only one correct answer for each question.
- Mark the correct answer with '✔' on the answer sheet provided. The correct way of marking is shown below. Use a pen to mark the answer.

Q. No.	a	b	C	d
		✔		

- Each wrong answer will have negative marking as indicated in the scoring key.

Section B

- Section B consists of 29 questions with a total of 71 points.
- The points for the questions in Section B vary depending on the number of answers and the complexity of the question. These points have been indicated along with the question.
- Contradictory answers will not be considered for marking.

SCORING KEY

NO. OF CORRECT ANSWERS: X

NO. OF INCORRECT ANSWERS: Y

SCORE INBO (THEORY): SECTION A: 3X – Y

SECTION B: 3X

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INDIAN NATIONAL BIOLOGY OLYMPIAD – 2016
SECTION A

CELL BIOLOGY (7 points)

1. (1 point) There are several types of enzyme catalyzed reactions. In one type of enzyme catalyzed reaction, in addition to the catalytic site to which the substrate (X) binds, the enzyme also has a site to which some other substance (Y) can bind. When Y binds to such an enzyme, the enzyme can still bind to the substrate but cannot convert it to the product. Which of the following will occur in such a case?

   i. The affinity of the enzyme for the substrate will reduce.
   ii. Vmax of the reaction will decrease.
   iii. Y will alter the conformation of X.
   iv. The conformation of the catalytic site will be altered by binding of Y.
   v. The effect of Y can be overcome by increasing the concentration of X.

   a. Only i, iii and v
   b. Only ii, iv and v
   c. Only i, ii and v
   d. Only ii and iv

2. (1 point) In an experiment, *E. coli* cells growing at 37°C were shifted to 20°C and grown for a few generations. Which of the following changes in the membrane would help the *E. coli* cells adapt to the new environment?
   a. Increase in the unsaturated fatty acid content.
   b. Increase in the number of integral membrane proteins.
   c. Increase in the phospholipid content.
   d. Increase in the length of the hydrophobic tail.

3. (1 point) The shaker (*sh*) gene in *Drosophila*, when mutated, shows a typical behavior of continuous leg shaking. When the action potential of axons of such a *shaker* mutant of *Drosophila* was studied, it showed the following graph.

1
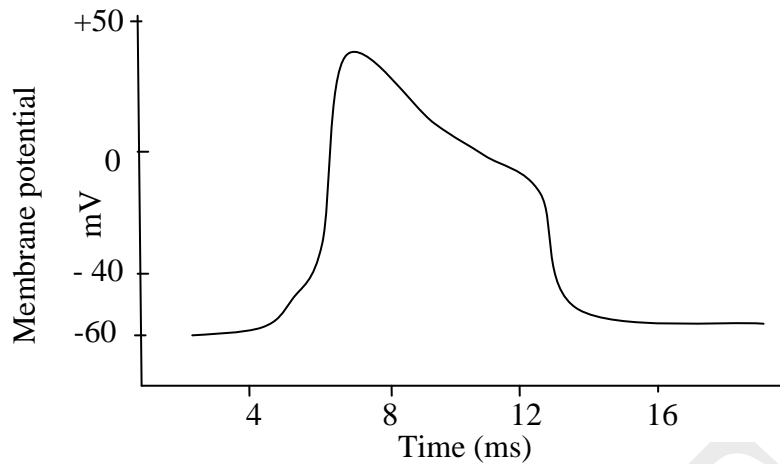
The graph indicates that the defect lies in the:

a. functioning of activation gate of voltage-gated Na^+ channel.

b. functioning of inactivation gate of voltage-gated Na^+ channel.

c. functioning of voltage-gated K^+ channel.

d. strength of the electrical stimulus.

4. (1 point) The nuclear membrane disappears during cell division. After completion of cell division, it re-appears during the interphase. Which of the following contributes towards formation of the nuclear membrane?

a. Spindle fibre proteins

b. Cytoskeletal elements

c. Endoplasmic reticulum

d. Golgi bodies

5. (1 point) Eosin is an acidic stain that is widely used for staining cytoplasm of eukaryotic cells. Which of the following is responsible for this specificity?

a. Ability of eosin to bind with water molecules in cytoplasm.

b. Ability of eosin to bind with amino acids in cytoplasm.

c. Eosin can cross the plasma membrane but cannot cross the nuclear membrane and hence accumulates in cytoplasm.

d. Ability of eosin to bind with carbohydrate moieties in the cytoplasm.

6. (1 point) In an experiment of mitotically dividing animal cells, nuclei of cells in G1 and G2 phases were removed. In the subsequent step, the G2 phase nuclei were introduced in enucleated cells of G1 phase. If these cells are cultured, what will be the consequence?

a. Cells will abort cell cycle and enter G0 phase.

b. Cells will shift directly from G1 to G2 phase.

2

c. Cells will continue to stay in G1 phase.

d. Cells will proceed from G1 to S phase.

7. (1 point) Propidium iodide (PI) is a dye that can intercalate and stain cellular genome upon cell fixation. The amount of DNA indicated by the fluorescence intensity of PI in a population of cells which are in different stages of the cell cycle is depicted in the following graph. P, Q and R respectively indicate:

a. (G2), (S & G1) and (M).

b. (G1), (G2&M) and (S).

c. (G1), (G2) and (S&M).

d. (S & G2), (G1) and (M).
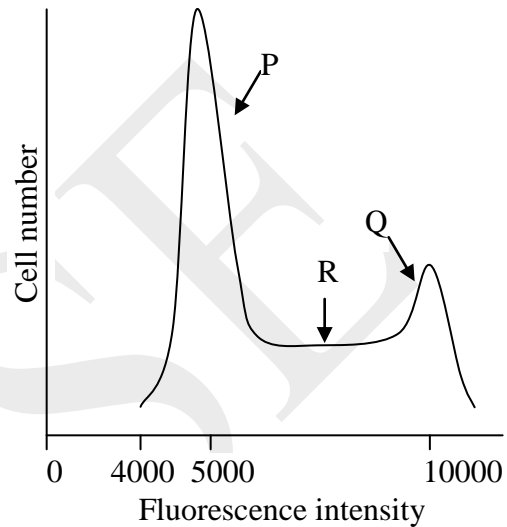
PLANT SCIENCES (3 points)

8. (1 point) The process of photosynthesis needs carbon dioxide to diffuse from the atmosphere into the leaf and into the carboxylation site of RUBISCO. This happens through a series of steps. Each step in this diffusion pathway imposes resistance to CO_2 diffusion. This is depicted in the diagram. Various resistances are listed below.

    i.   Boundary layer resistance

    ii.   Stomatal resistance

    iii.   Liquid phase resistance

    iv.   Intercellular air space resistance

3
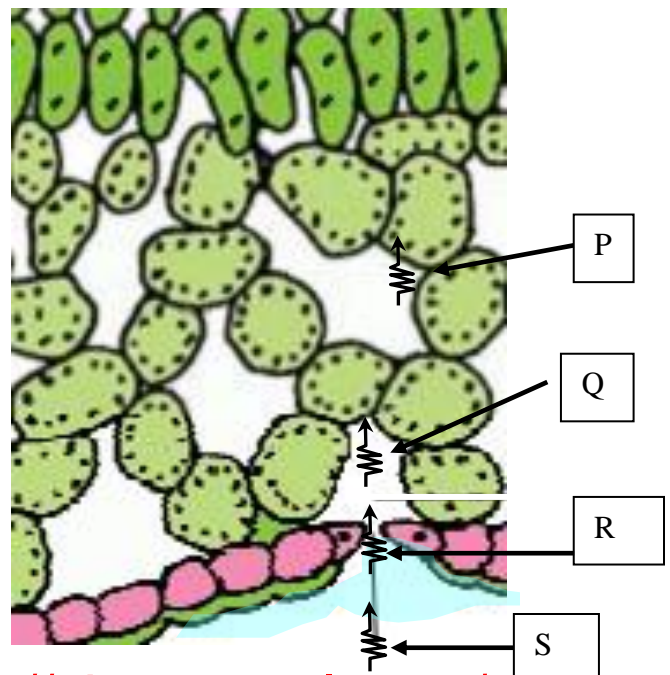
Which of the following shows the correct combination?

a. P – i; Q – iii; R – ii; S – iv
b. P – i; Q – ii; R – iii; S – iv
c. P – iii; Q – iv; R – ii; S – i
d. P – iv; Q – iii; R – ii; S – i

9. (1 point) In Angiosperms, double fertilization provides the stimulus to the formation of seeds. Growth (measured as change in volume) of ovule, embryo and endosperm in *Pisum* is plotted in the graph.

I, II and III respectively represent:

a. endosperm, ovule and embryo.
b. ovule, endosperm and embryo.
c. embryo, ovule and endosperm.
d. endosperm, embryo and ovule.
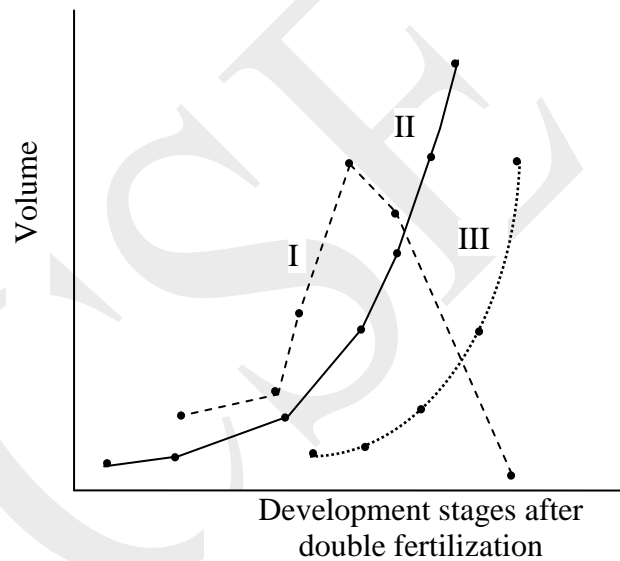
10. (1 point) The diploid chromosome number in the leaf cell of *Pisum* is 14. The diagram given below depicts the ovule structure immediately after fertilization. (Note: PEN refers to primary endosperm nucleus)
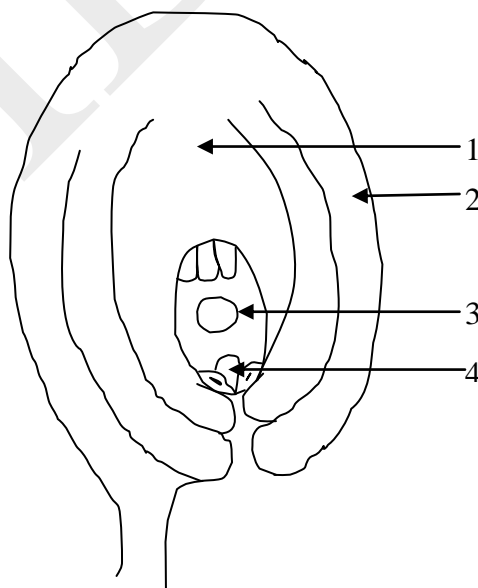
Structures 1 – 4 and the number of chromosomes present in them respectively are:

4

a. nucellus:7; integument:14; PEN:21; egg cell:7.

b. nucellus:14; integument:14; PEN:21; zygote:14.

c. embryo sac:7; integument:14; PEN:14; zygote:14.

d. nucellus:14; integument:7; PEN:14; zygote:14.

ANIMAL SCIENCES (12 points)

11. (1 point) The table shows body weight and food intake of a few selected animal species.

Animal species	Average body weight	Average food intake/day
Black Bear *Euarctus americanus*	135 kg	3.9 kg
Common Shrew *Sorese cinereus*	5 gm	13 gm
Pigeon *Columba liva*	300 gm	100 gm
Horse *Equus caballus*	500 kg	12 kg

Based in the data provided, analyze the following statements.

1) Smaller the animal, higher is the metabolic rate.

2) Larger the animal, greater is the energy requirement per unit body weight leading to larger intake of food.

3) Mammals consume larger proportion of their own weight as food daily compared to birds.

4) Demand for food per unit of body mass increases as the metabolic rate increases.
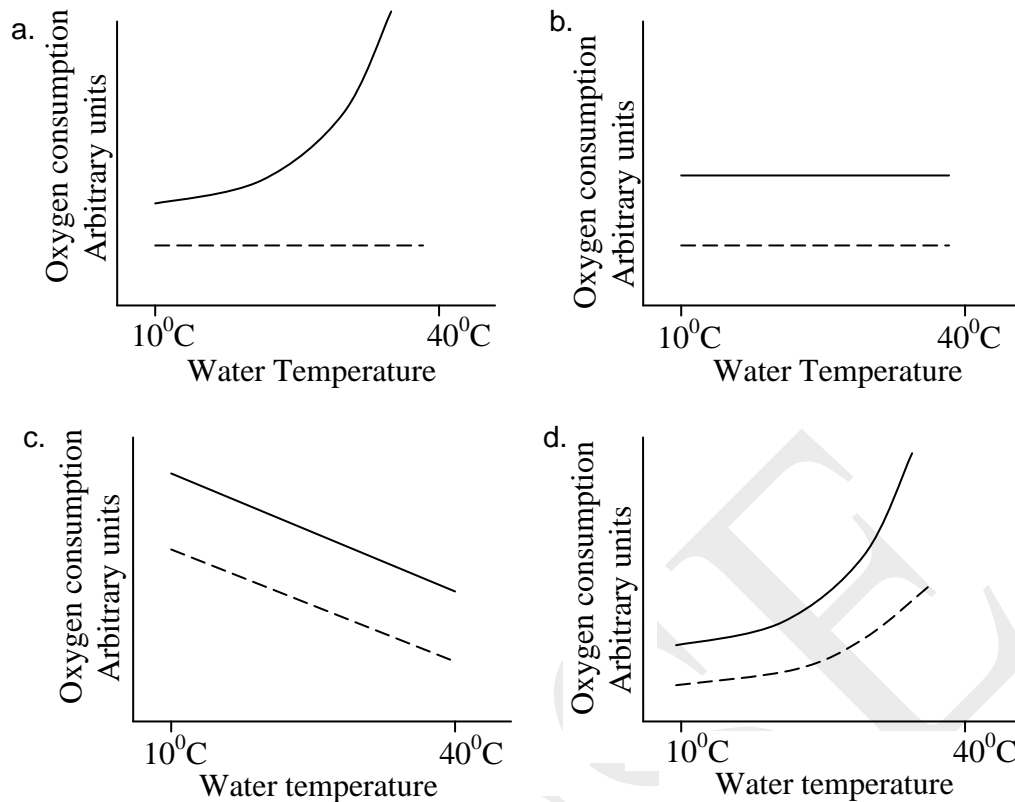
The correct statements are:

a. 1 and 2

b. 1 and 4

c. 2 and 3

d. 3 and 4

12. (1 point) The flat body plan of platyhelminthes helps them to:

a. attain effective locomotion in any direction.

b. minimize the loss of body fluid and maximize surface area.

c. facilitate successful reproduction.

d. maximize exposure of animal's cells/ tissues to the surrounding medium.

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13. (1 point) In which of the following animals is the 'heart' located dorsally?

a. Flightless birds

b. Lungfish

c. Snakes

d. Crabs

14. (1 point) Metamerism is a salient feature found in Annelids, dividing the body into a series of similar segments, each containing repeated arrangements of many of the internal organ systems. One of the following systems which **is not** metameric is the:

a. integumentary system.

b. nervous system.

c. digestive system.

d. excretory system.

15. (1 point) Which one of the following characteristics found in birds contributes LEAST towards the adaptation for flight?

a. Keratinized beak

b. Hind limbs

c. Endothermy

d. High metabolic rate

16. (1 point) The slow rate of oxygen diffusion in water limits the efficiency of oxygen distribution from gas exchange surface to sites of cellular respiration. This is true for:

a. only aquatic animals.

b. only air-breathing animals.

c. only those animals in which no circulatory system has developed.

d. all animals.

17. (1 point) Fish utilize oxygen dissolved in water. When the temperature of water rises, it can pose physiological stress to the fish as solubility of oxygen in water decreases. Which of the following graphs correctly depicts the oxygen consumption rates of resting fish and active fish under these conditions?

Note: Oxygen consumption by active fish is indicated by solid line and by resting fish is indicated by dashed line.

6

a.

Oxygen consumption
Arbitrary units

10^0C 40^0C
Water Temperature

b.

Oxygen consumption
Arbitrary units

10^0C 40^0C
Water Temperature

c.

Oxygen consumption
Arbitrary units

10^0C 40^0C
Water temperature

d.

Oxygen consumption
Arbitrary units

10^0C 40^0C
Water temperature

18. (1 point) Environmental variables that limit respiratory gas exchange in animals can be explained by Fick's Law:

$$Q = D.A.\frac{P1 - P2}{L}$$

      Where, Q= rate of diffusion. It is affected by

i.   D = diffusion coefficient (depends on the type of diffusing substance, medium and temperature)

ii.   A= cross sectional area

iii.   P1and P2 = partial pressures across two locations

iv.   L = path length

In fish, countercurrent exchange of gases across the gill lamellae results in very efficient gas exchange. Which of the following factors has the maximum influence on it?

a. D

b. A

c. P1-P2

d. L

19. (1 point) Birds can sustain high levels of activity much longer than mammals even at high altitudes. Which of the following features found in birds helps in this?

a. More efficient expansion and contraction of air sacs as compared to mammals.

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b. Size of lungs larger than that of a mammal of comparable size.

c. Air sacs allowing unidirectional air flow with minimum dead space.

d. Circulatory system with more number of erythrocytes per unit volume of blood as compared to mammals.

20. (1 point) Oxygen saturation curves of haemoglobin for four different species at various partial pressures of oxygen are depicted in the graph.
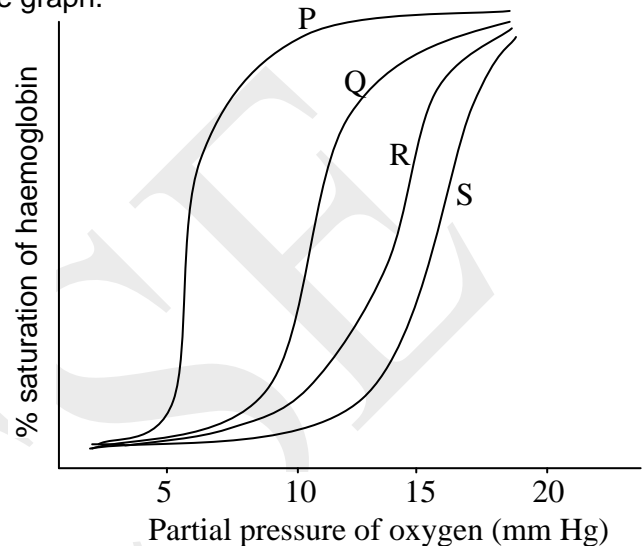
P, Q, R and S respectively indicate:

a. mouse, cat, sheep and elephant.

b. elephant, dog, cat and earthworm.

c. crow, horse, dog and cat.

d. crab, elephant, human and shrew.

21. (1 point) Which of the following is the correct depiction of circulatory pattern of water in poriferans?
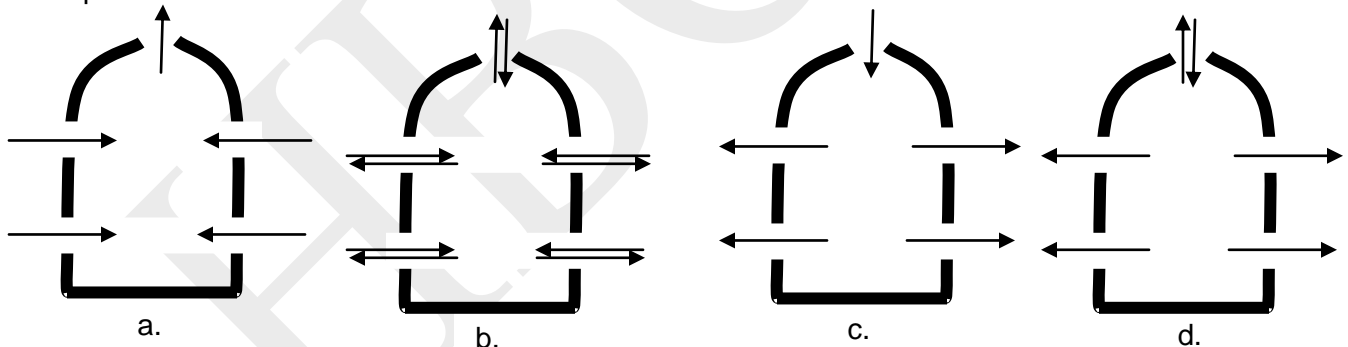
22. (1 point) The volume of blood pumped by heart per minute is referred to as cardiac output. In an adult human, it is approximately 5 L. But, the amount of blood received by various organs of the body varies. Which of the following depicts correct hierarchy in terms of the amount of blood received by four key organs of human body viz. brain, skeletal muscles, kidney and skin?

a. Skin < brain < skeletal muscles < kidney

b. Skin < kidney < skeletal muscles < brain

c. Kidney < skeletal muscle < skin < brain

d. Skin < brain < kidney < skeletal muscles

8

GENETICS & EVOLUTION (1 point)

23. (1 point) The rate of evolution varies in different lineages. For example: It is higher in rat lineage than in human lineage. Which of the following statements is correct?

a. Rate of evolution would be the same for the coding and non-coding regions for a given species.

b. Errors during DNA replication of somatic cells are the major source of mutations that leads to evolution.

c. Rats have shorter generation time as compared to humans. Thus, more rounds of germ cell divisions would lead to more DNA replication errors. This can hasten rate of evolution.

d. Humans show lower rate of metabolism than rats. This would lead to fewer errors during DNA replication thereby reducing the rate of evolution.

ECOLOGY (3 points)

24. (1 point) A common method used to compare the patterns of species richness and abundance between communities involves plotting the relative abundance of each species against rank (where rank is defined by the order of species from the most to the least abundant). The most abundant species is plotted first along the x-axis, with the corresponding value on the y-axis being the value of relative abundance. The following diagram depicts the rank-abundance curve for two forest communities 1 and 2.
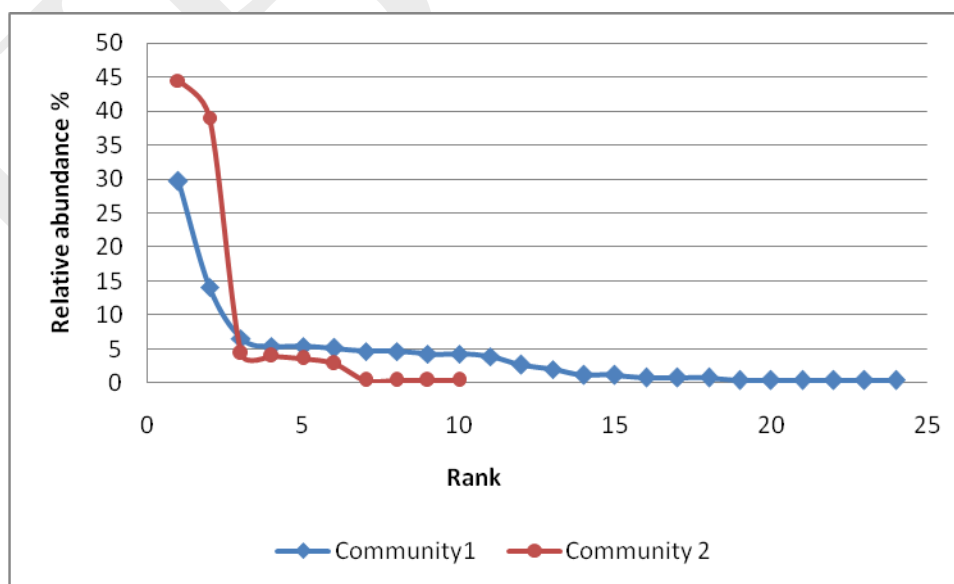
A few statements regarding the forest communities are made below.

i. Community 1 has a higher number of species.

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ii. Community 2 shows a higher degree of evenness in terms of abundance.

iii. The most dominant member of community 1 has the highest relative abundance among all the species depicted in the graph.

Based on the graph, the true statement/s is/are:

a. i , ii and iii

b. iii only

c. i and iii only

d. i only

25. (1 point) An experiment to understand the relationship between a herbivorous crab *Mithrax forceps* and the coral *Oculina arbuscula* was undertaken in a shallow water coastal ecosystem. Observation on predation of crab, growth of algae, growth and mortality of corals were made. The following graphs indicate the results obtained during the experiment.
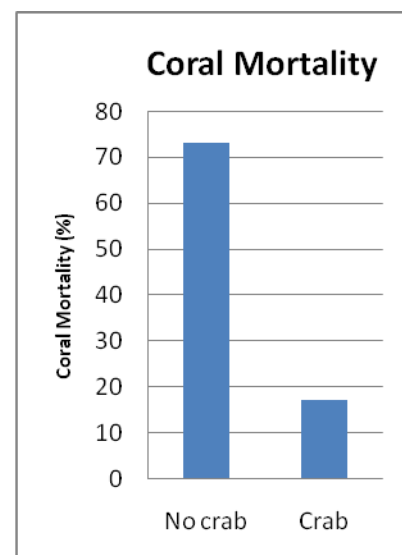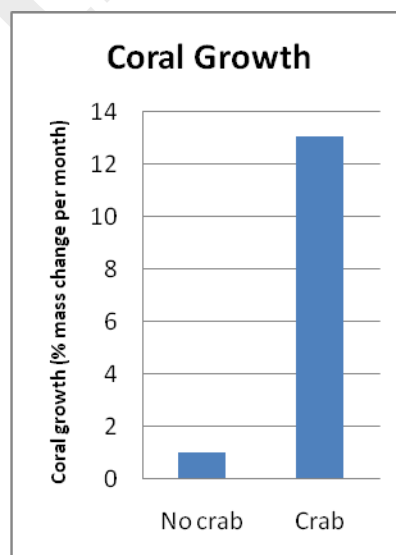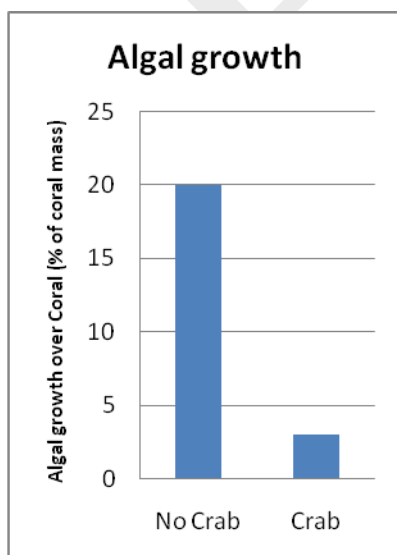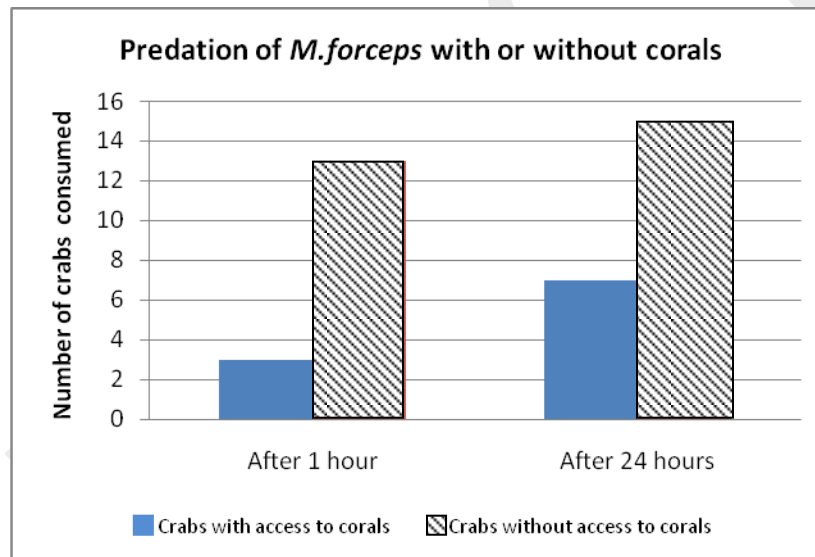
A few statements based on the results obtained are made.

i. The presence of crabs has a negative influence on algal growth and positive influence on coral growth.

ii. Presence of *M. forceps* is obligatory for the survival of *O.arbuscula*.

iii. The coral species plays an important role in preventing predation of *M. forceps.*

iv. The algae outcompete *O.arbuscula* in the absence of M. Forceps.

Which of these statements are true?

a. i, ii and iii only

b. i and iv only

c. i, iii and iv only

d. iii and iv only

26. (1 point) Two ecological pyramids are drawn below. If 'I' represents aquatic and 'II' represents terrestrial ecosystem, which of the following statements are true?
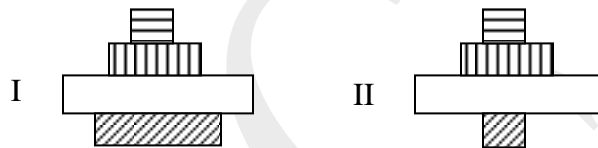
i. Pyramid 'I' is based on biomass.

ii. Pyramid 'II' is based on numbers.

iii. The unshaded box in pyramid 'I' represents zooplankton and in pyramid 'II' it represents insects.

iv. Neither 'I' nor 'II' can be based on energy.

a. ii and iii only

b. i and iii only

c. i, ii and iv only

d. i, ii, iii and iv

BIOSYSTEMATICS (3 points)

27. (1 point) Study the cladograms below that depict evolutionary history of species M, N, O, and P.

(I)

(II)

(III)

(IV)
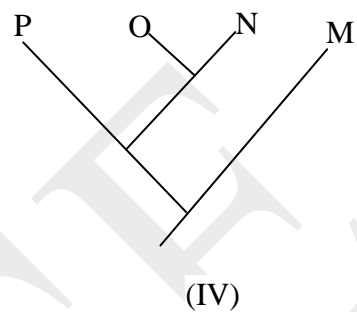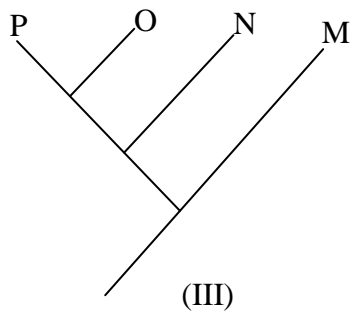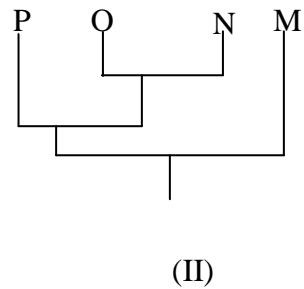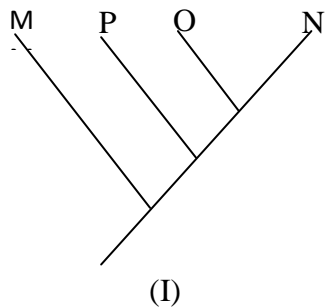
Which one of the above cladograms differs from the rest?

a. I

b. II

c. III

d. IV

28. (1 point) A cladogram that classifies five species (M, N, O, P and Q) is shown below.
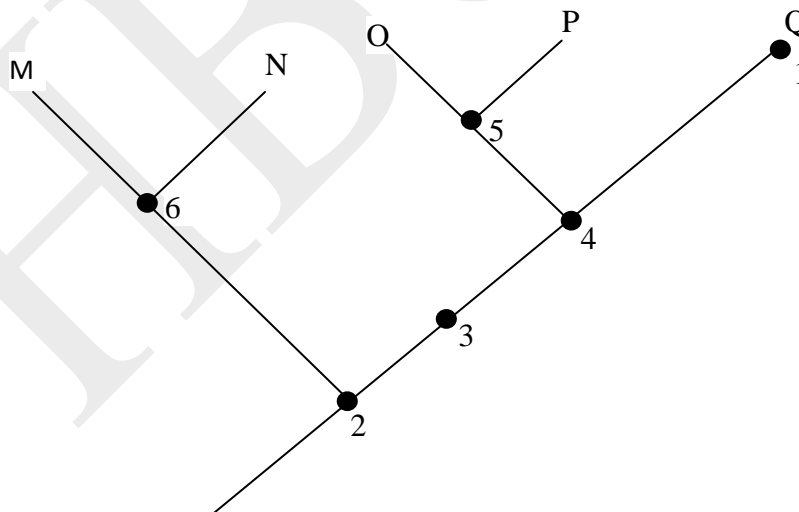
Which of the six dots in the cladogram corresponds to the most recent common ancestor of N and P?

a. 2

b. 3

c. 5

d. 6

12

29. (1 point) The gene *cox2* encodes one of the subunits of cytochrome c oxidase (Complex IV). Its distribution and expression in mitochondria and nuclei of four extant plant species is given below.

Species	Gene		mRNA	
	Mitochondria	Nucleus	Mitochondria	Nucleus
1	+	+	+	+
2	+	-	+	-
3	-	+	-	+
4	+	+	+	-

Mark the most appropriate phylogenetic classification that is also compatible with the endosymbiotic theory.

a.

Gene transfer

Loss of function

Loss of gene

b.

Loss of function

Secondary loss of gene

Secondary loss of gene

c.

Secondary loss of gene

Secondary loss of gene

Gain of function

d.

Gene transfer

Secondary loss of gene

Loss of function
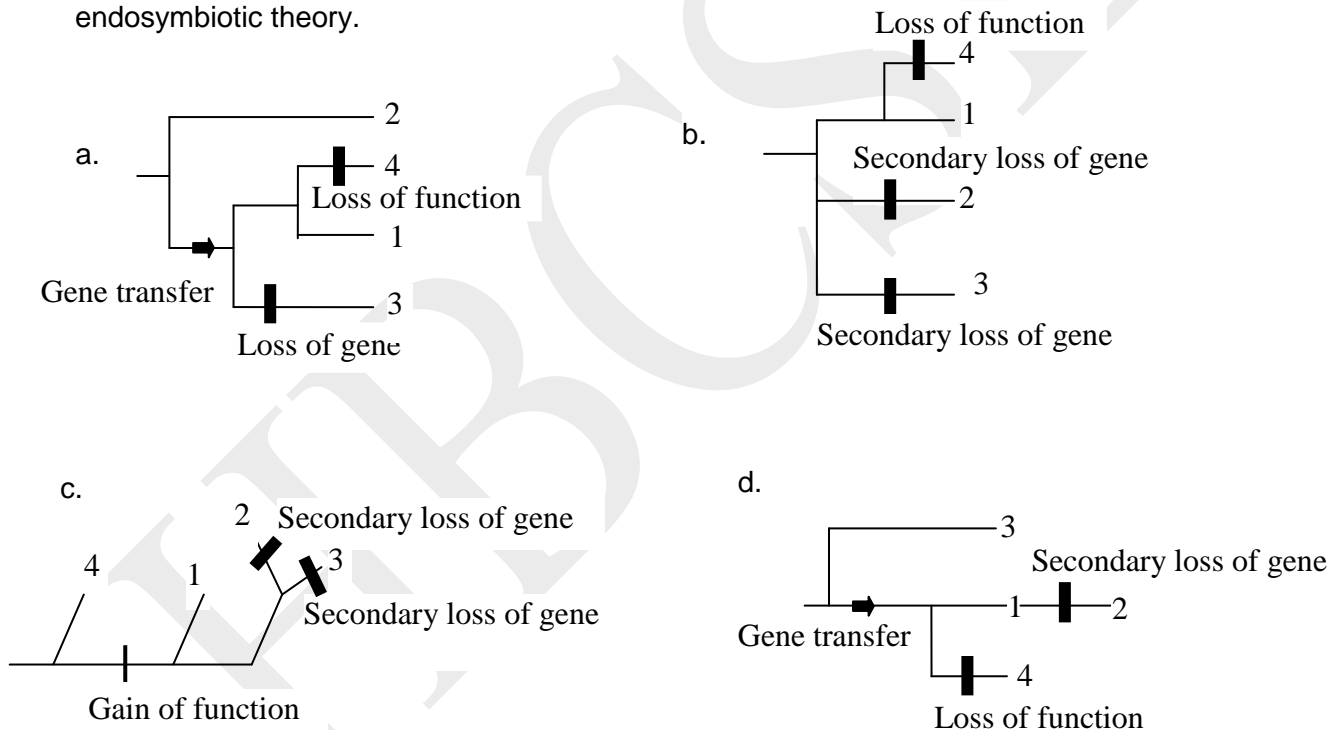
********* END OF SECTION A *******

INDIAN NATIONAL BIOLOGY OLYMPIAD – 2016
SECTION B

NOTE:

- *Write all answers in the **ANSWERSHEET ONLY.***
- *Only the answer sheets will be collected at the end of the examination.*

CELL BIOLOGY (14 points)

30. (2 points) A glucose-fed yeast cell growing in an aerobic environment consumes 1.8 g of glucose per unit time. If these cells are moved to anaerobic environment, how many moles of glucose the cells will consume to generate ATP at the same rate? (Write the answer in decimal form.)

    Answer: _____moles

31. (2 points) Biological membranes show differential permeability to different solutes that might be present outside or inside the cell. However, artificial membranes made up of lipid bilayer may differ in their permeability as compared to biological membranes.

    The permeability of the following solutes across *E. coli* membrane versus an artificial lipid bilayer was plotted. Deduce the position of each of the following solutes in the graph.

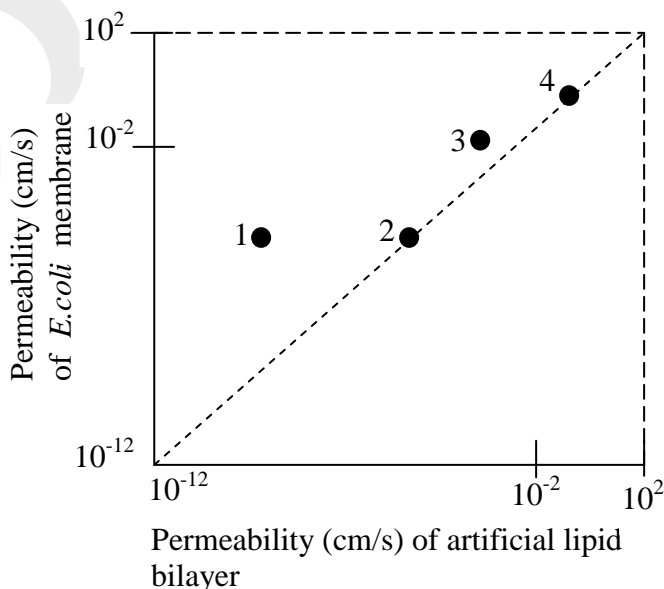   W: Carbon dioxide

    X: Water

    Y: Glucose

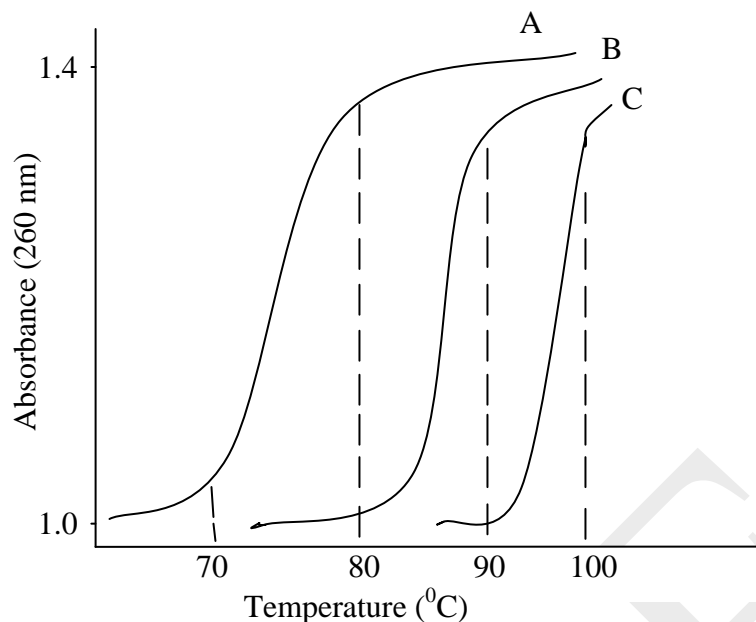   Z: Ethanol

    Points 1, 2, 3 and 4 represent:

    1: ___

    2: ___

    3: ___

    4: ___

32. (3 points) Thermal denaturation of three double stranded DNA samples is represented in the figure.

State whether each of the following statements is true (T) or false (F).

a. It is likely that GC content of sample 'A' is highest among all. _____

b. If all three DNA samples are polyG:polyC homopolymers, then 'A' is likely to be the longest of the three. _____

c. If A, B, C represent the same DNA sample then the melting curves obtained (from A → C) could be due to increasing concentration of salt in the solutions. _____

d. The graph indicates that double helices have lower molecular absorptivity for UV light as compared to denatured single strands. _____

e. The pattern of thermal denaturation shown is characteristic and unique for each DNA molecule and will not change if external conditions such as pH or rate of cooling are changed. _____

f. If phosphate and pentose sugar moieties are cleaved from DNA molecule 'A', it will show absorbance close to 1.0. _____

33. (1+2 = 3 points) A 5 kb circular plasmid has three EcoRI sites at positions 500, 3200 and 4100 as shown below. Numbering starts from the nucleotide denoted by 1.


15
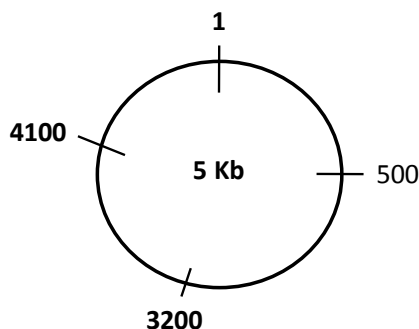
This plasmid was <u>partially</u> digested with EcoRI. Partial digestion means that only some of the sites are cut by the enzyme. Assume that all plasmids are cut at least at one site.

(A) The total number of bands visible in the gel after the restriction digestion will be:

Answer: _____ .

(B) In the schematic of the agarose gel shown, indicate the banding pattern that will be obtained. **Only an entirely correct band pattern will be given 2 points.**
(MW: molecular weight)
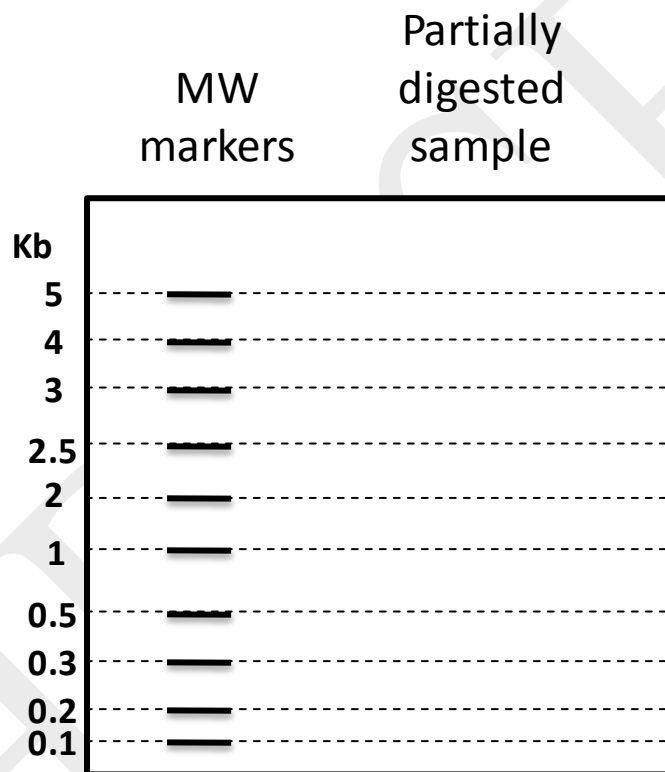
34. (2+2 = 4 points) Complete digestion of a plasmid with a restriction enzyme means that all the sites for this enzyme in all the plasmid molecules are cut. Partial digestion means that only some of the sites for this enzyme are cut.

For expression of a recombinant protein, you wish to clone its gene under the promoter P in the plasmid shown below. The direction of the arrow shows the direction of transcription. (*ori* represents origin of replication and *amp^r* represents the gene for ampicillin resistance)

16
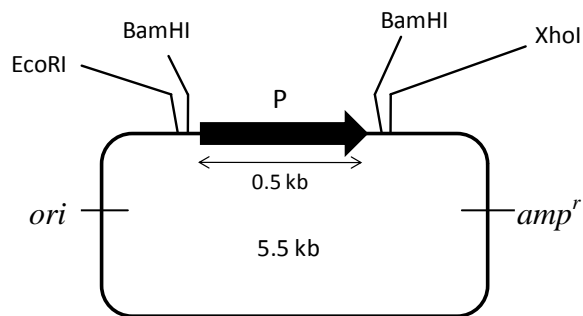
(A) Determine whether each of the following treatments can be used to successfully clone and express the gene. Indicate by yes (Y) or no (N).

a. Complete digestion with XhoI. _____
b. Partial digestion with EcoRI. _____
c. Complete digestion with BamHI. _____
d. Partial digestion with BamHI. _____

(B) A molecular biology student decides to use a pair of enzymes instead of a single enzyme in order to ensure insertion of the gene of interest in the correct orientation. Indicate which pair of restriction enzymes can be used to clone the gene for expression. (**Only an entirely correct answer will be given 2 points.**) Choose from the options and fill in the blanks.

Answer: _____ digestion with enzyme _____ and _____ digestion with enzyme _____.

Options:
(I) Partial
(II) Complete
(III) EcoRI
(IV) BamHI
(V) XhoI

PLANT SCIENCES (9 points)

35. (2 points) The diagram given below shows 'pressure flow model' of phloem translocation. The phloem sap is conducted from source cells to different parts of plant body (sink cells) where it is metabolized or stored in the form of carbohydrates. The movement of solution is shown by arrows P, Q, R and S.
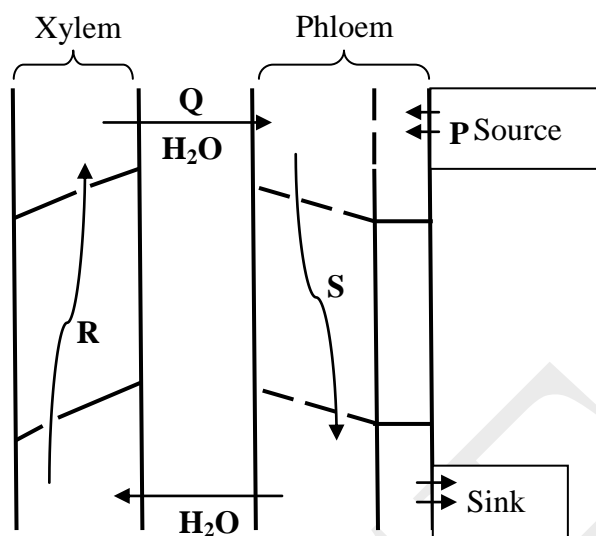
Match P, Q, R and S with the most appropriate option from those given below.

a. Active transport
b. Passive transport
c. Pressure driven flow
d. Transpirational pull

Answer: P: _____   Q: _____   R: _____   S: _____

36. (2 points) 'A' and 'B' are leaves belong to the same tree. The morphology of the two leaves vary in shape, size, thickness and in the number of lobes.

 Mark each of the following statements as true (T) or false (F).

a. Leaf 'A' is from the top of canopy and leaf 'B' is from the bottom. _____
b. Leaves in the upper tree canopy are thicker as they receive higher intensity of light. _____
c. Leaf 'B' can lose heat by convection more easily than leaf 'A' as it is more lobed and small. _____
d. Leaves lower in the canopy will have more chlorophyll a: b ratio as compared to leaves from the top of the tree. _____

37. (0.5 + 0.5 + 2 = 3 points) When growth rings from a tree were studied in order to understand the history of the climate, the following pattern was obtained (figure I). Figure II shows the magnified picture of tree rings. Answer the following questions.
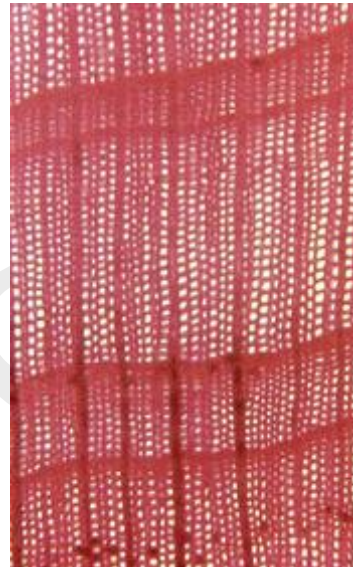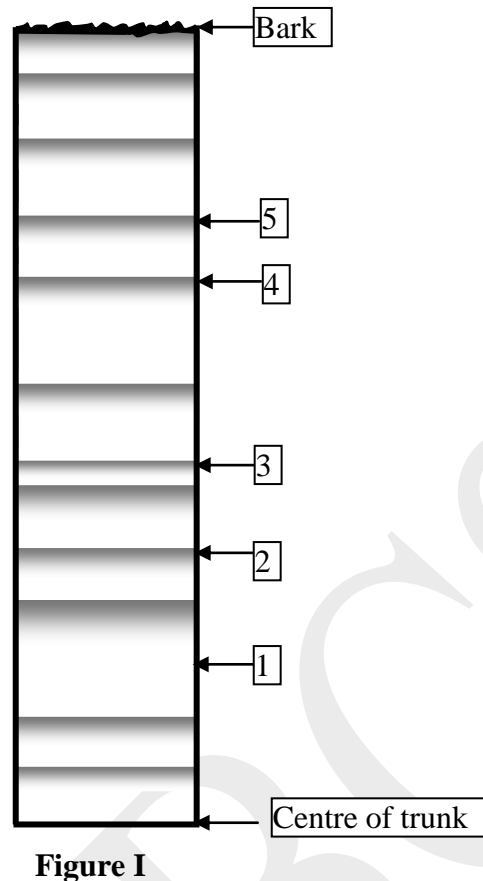
Figure I

Figure II

(A) Age of the tree is: ____years

(B) Which number/s in figure I indicate/s early wood:_____

(C) Mark the following statements as true (T) or false (F).

a. Arrow 3 indicates time period of heavy rain fall. _____

b. In the 3rd and 8th year of tree age, there was optimum availability of factors required by plant. _____

c. Figure I and figure II cannot belong to the same specimen because figure I represents an angiosperm and figure II represents a gymnosperm. _____

d. Dark regions in Figure II indicate the sap wood formed during the four year time period. _____

38. (2 points) Photosynthesis in plants occurs due to the presence of chlorophyll and other accessory pigments present in leaves. When absorbance of chlorophyll pigments was

studied in different layers of tissues in a dorsiventral leaf, following graph was obtained. The lines indicate data obtained when the experiments was carried out in duplicate.
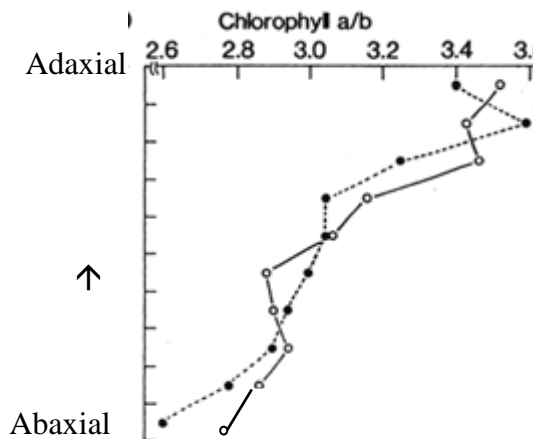
Mark the following statements as true (T) or false (F).

a. The graph indicates that palisade cells are richer in chlorophyll content as compared to spongy mesophyll cells. _____

b. Spongy mesophyll cells are more adapted to gather available light which is then passed on to the reaction centre. _____

c. If instead of chlorophyll estimation, invitro reduction of redox indicator is studied, it will show the same trend along the two surfaces. _____

d. (Shade-sun) plant pair will show the same trend that is observed for the graph of (abaxial — adaxial) surface. _____

ANIMAL SCIENCES (7 points)

39. (2.5 points) A urine test was conducted for a person as a routine check-up programme. It showed the following results:

   I. Colour: light yellow

  II. pH: alkaline

 III. Glucose: Nil

 IV. Amylase: 500 units

Analyse the following interpretations and mark them as either correct or incorrect by putting tick marks (✓) in the appropriate boxes.

a. The results do not indicate any abnormality and all four factors depend on diet consumed.

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b. The results are indicative of liver dysfunction as well as kidney homeostasis dysfunction.
c. The results indicate that the person is on heavy carbohydrate diet.
d. The presence of amylase is likely to indicate pancreatitis while alkaline pH can correlate to diet consumed.
e. The results are indicative that the person is dehydrated and starved which has led to defective glomerular filtration.

Interpretation	Correct	Incorrect
a.		
b.		
c.		
d.		
e.		

40. (2.5 points) Partial pressures of carbon dioxide (Pco_2) in body fluids of four animals (I, II, III and IV) when they are at rest are shown.
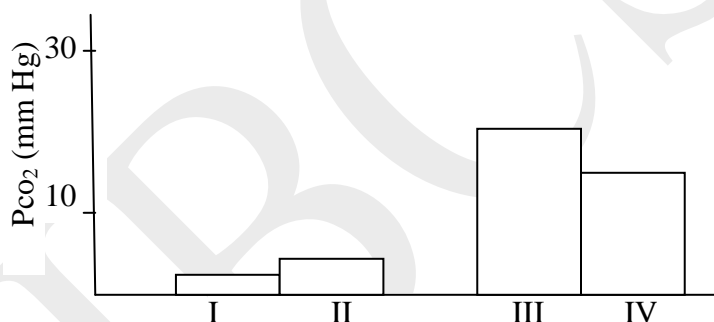
Mark the following statements as true (T) or false (F).

a. Animals in I and II represent invertebrates while III and IV represent vertebrates. _____
b. Mode of gas exchange for animals I and II is most likely to be aquatic while for III and IV to be terrestrial. _____
c. The body fluids of animals III and IV must be much more acidic than I and II. _____
d. Bicarbonate concentration in body fluids of III and IV will be higher than that in I and II. _____
e. Rate of metabolism of animals III and IV is likely to be higher than that of animals I and II. _____

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41. (2 points) A typical insect leg is depicted below.
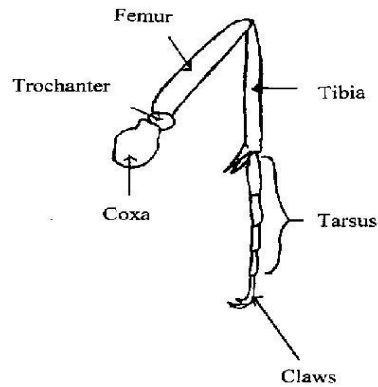
Legs of insects can show various modifications which can be correlated to their functions. Descriptions of various modifications are listed in column I. Match these descriptions with the insects in which they are found (column II) and related function (column III).

Modification	Insect	Function
(A) All three pairs of legs are long and narrow with thin segments.	I. Grasshopper	(M) Fossorial (digging)
(B) Hind legs are modified and characterized by elongated strong femur and elongated tibia.	II. Mole Cricket	(N) Saltorial (jumping)
(C) Femur of the forelegs is powerful, stout and short and bears tines (sharp small projections).	III. Praying Mantis	(O) Cursorial (running)
(D) Long foreleg with elongated coxa and large femur.	IV. Ant	(P) Raptorial (grasping)

Write appropriate numeral and alphabet against each modification in the table. **Only an entirely correct row will be given 0.5 points.**

Modification	Insect	Function
A		
B		
C		
D		

GENETICS & EVOLUTION (18 points)

42. (2 points) The agouti gene contributes to coat colour in mice. In an agouti mouse, the wild type allele is responsible for the yellow and black stripes of hair strands. An insertion mutation in the agouti gene results in yellow mice due to completely yellow hair strands. Whenever any two agouti mice are crossed, the result is always an agouti mouse.

> **Cross 1:** Agouti x Agouti → All agouti

Any cross between an agouti and a yellow mouse results in agouti and yellow progeny mice in equal proportion.

> **Cross 2:** Agouti x Yellow → Agouti : Yellow :: 1:1

Any cross between two yellow mice results in agouti and yellow progeny mice in unequal proportion.

> **Cross 3:** Yellow x Yellow → Agouti : Yellow :: 1:2

The gel profile of the genes found in agouti and yellow mice in Cross 3 is depicted below.
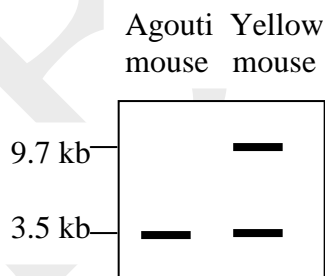
Analyse the following interpretations and mark them as either correct or incorrect by putting tick marks (✓) in the appropriate boxes.

a. With regard to coat color, mutant allele and wild type alleles are co-dominant.
b. Mutant allele in homozygous condition gives yellow coat color while in heterozygous condition gives agouti coat colour.
c. The mutant allele behaves as recessive in some conditions while dominant in other conditions.
d. The mutant allele is lethal when present in two copies.

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Interpretation	Correct	Incorrect
a.		
b.		
c.		
d.		

43. (2 points) In insects such as *Drosophila*, both X and Y chromosomes are found. However, the sex determination is different than that in mammals. The ratio of X chromosomes to autosomes (A) determines sex in these insects while Y chromosome contains genes necessary for male fertility. E.g. Genotype XX: 2A or XXYY: 2A indicates normal female and genotype XY: 2A indicates normal male.

For each of the genotypes listed, write the alphabet corresponding to the correct phenotype of *Drosophila.* Choose from the options given.

Genotype	Phenotype
XO:2A	
XXY:;2A	
X:3A	
XXX:2A	

Options:
a. Fertile male
b. Fertile female
c. Sterile male
d. Sterile female
e. Metafemale
f. Metamale

44. (2 points) In nature, summer squash fruit is found in three colours, namely, white, yellow and green. When a white fruit variety (genotype WWYY) was crossed with green variety (genotype wwyy), the progeny obtained in the F2 generation was as follows:

F2 generation - white : yellow: green :: 12:3:1.

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Mark the following statements as true (T) or false (F).

a. Gene W shows epistatic effect over gene Y. _____

b. W and Y are allelic forms of the same gene. _____

c. Gene Y is dominant over its allelic form y and is responsible for yellow fruit. _____

d. Presence of both genes W and Y are essential for the fruit colour. _____

45. (2 points) The following pedigree depicts the transmission of myopia (near sightedness) in a family.
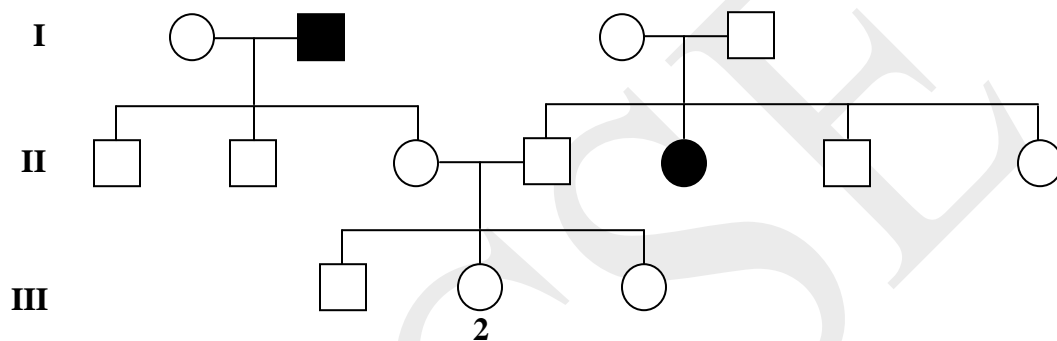
What is the probability that individual III 2 will have myopia? Indicate the answer as fraction.

Answer: _____

46. (3 points) The wild type (normal) fruit fly, *Drosophila melanogaster* has straight wings and long bristles. Mutant strains have been isolated that show either curled wings or short bristles. It is known that all genes for these phenotypes are located on separate chromosomes.

When flies with straight wings and short bristles were self-crossed (Cross I), the following results were obtained:

Straight wings , long bristles	30
Straight wings, short bristles	90
Curled wings, long bristles	10
Curled wings, short bristles	30
Total	160

Note: Assume A and a as alleles for wing structure and B and b as alleles for bristle length.

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(A) When flies used for cross I were then used to cross with flies with curled wings short bristles, all flies in the progeny had short bristles. What is the genotype of the parental curled winged flies?

Answer: _____

(B) When straight winged long bristle flies were crossed among themselves, all the progeny obtained had the same phenotype. Designate the correct genotype/s to each of the parents.

Parent 1	Parent 2

47. (2 points) Some genes evolve rapidly while some others are highly conserved. The nucleotide substitution that occurs in a gene is of two types: Synonymous and Non-synonymous. They are defined as follows:
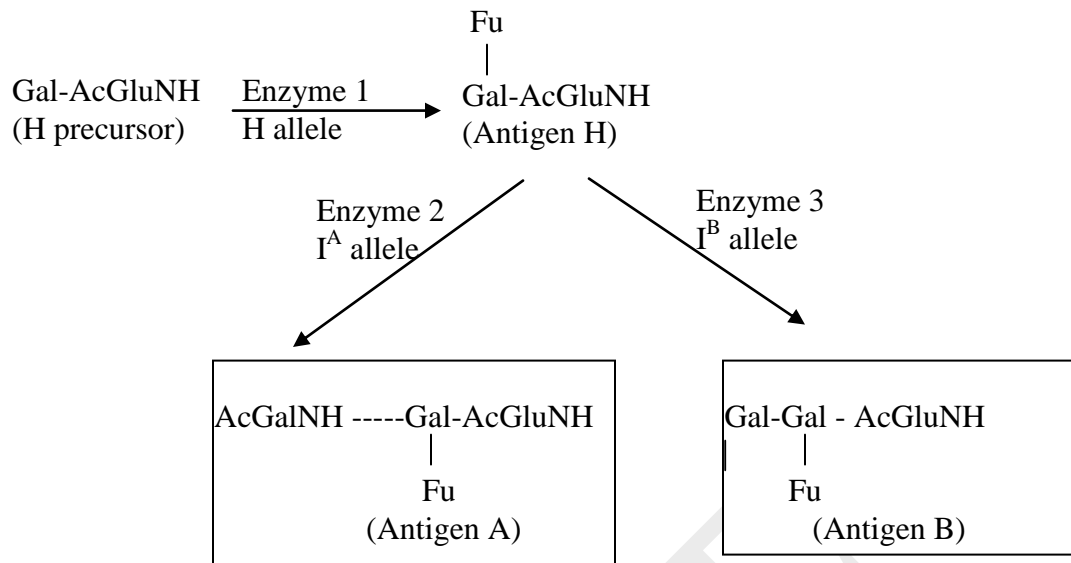
Synonymous substitution: Change in a single nucleotide that does not alter the encoded amino acid.

Non-synonymous substitution: Change in a single nucleotide that alters the encoded amino acid.

 Mark the following statements as true (T) or false (F):

a. Rate of non-synonymous mutation will always be higher than that of synonymous one if the gene is highly conserved. _____

b. Rate of non-synonymous and synonymous mutations could be comparable for a rapidly evolving gene. _____

c. Rate of non-synonymous and synonymous mutations will depend on the number of amino acids present in the protein. _____

d. Greater rate of non-synonymous mutation will indicate that the gene is more tolerant to nucleotide changes. _____

48. (3 points) The ABO blood group system is characterized by the presence of antigens on the surface of the red blood cells. The basic precursor molecule present on red blood cells is galactose-acetyl glucoseamine. It gets modified by the action of three enzymes (1, 2 and 3) which are products of three alleles namely, allele H, I^A and I^B. The pathway of formation of these antigens is shown below.

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Fu
|
Gal-AcGluNH — Enzyme 1 → Gal-AcGluNH
(H precursor)   H allele   (Antigen H)

Enzyme 2
I^A allele

Enzyme 3
I^B allele

AcGalNH -----Gal-AcGluNH
|
Fu
(Antigen A)

Gal-Gal - AcGluNH
|
Fu
(Antigen B)

Study the following pedigree and assign genotypes to the individuals **I 2, II 3** and **II 4**.

Alphabets indicate blood groups.
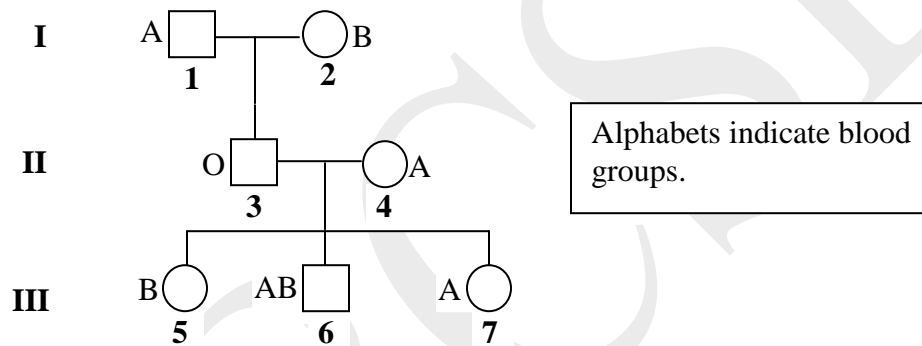
Assume that alleles *H, A* and *B* are responsible for the synthesis of antigens H, A and B respectively. Using symbols H, h, I^A, I^B and I^O, indicate **ALL** possible genotypes of:

I 2 : _____   **II 3**: _____   **II 4**: _____

49. (2 points) The following pedigree depicts the relationships between individuals in a family. Calculate the genetic relatedness of individual marked as SELF with the individuals A, B, C and D.

Genetic relatedness between the following: (Write your answer in decimals.)
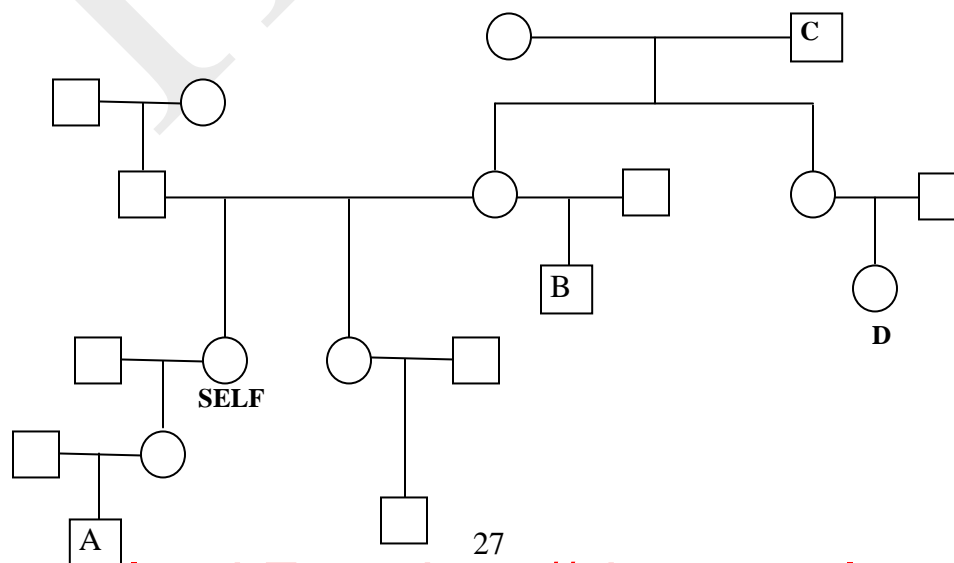
(I) Self and A: _____

(II) Self and B: _____

(III) Self and C: _____

(IV) Self and D: _____

ETHOLOGY (8 points)

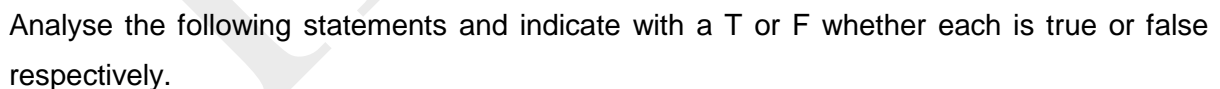50. (2 points) Bird songs are often analysed using sonagrams or sound-spectograms, in which song frequencies are plotted against time. The figure below shows the sonagrams of the six Great Tit *Parus major* individuals recorded in six countries across the world.

Analyse the following statements and indicate with a T or F whether each is true or false respectively.

a. The differences in the sonagrams between the six birds, which come from different populations, clearly suggest that these songs are "genetically determined". _____

b. Considering that these birds live in different environments, it could be deduced that these songs are purely "environmentally determined". _____

c. The differences in the songs between the birds are due to "gene-environment interactions". _____

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d. If the birds live in different environments, the three individuals in column I possibly live in open grasslands and those in column II in dense forests. _____

51. (2 points) Frogs and toads, as well as birds, use species-specific vocalisations as apparent mate-attraction signals. The figure below shows data from two closely-related frog species, *Hyla ewingi* and *H. verreauxi*, from southeastern Australia, whose ranges overlap partially.
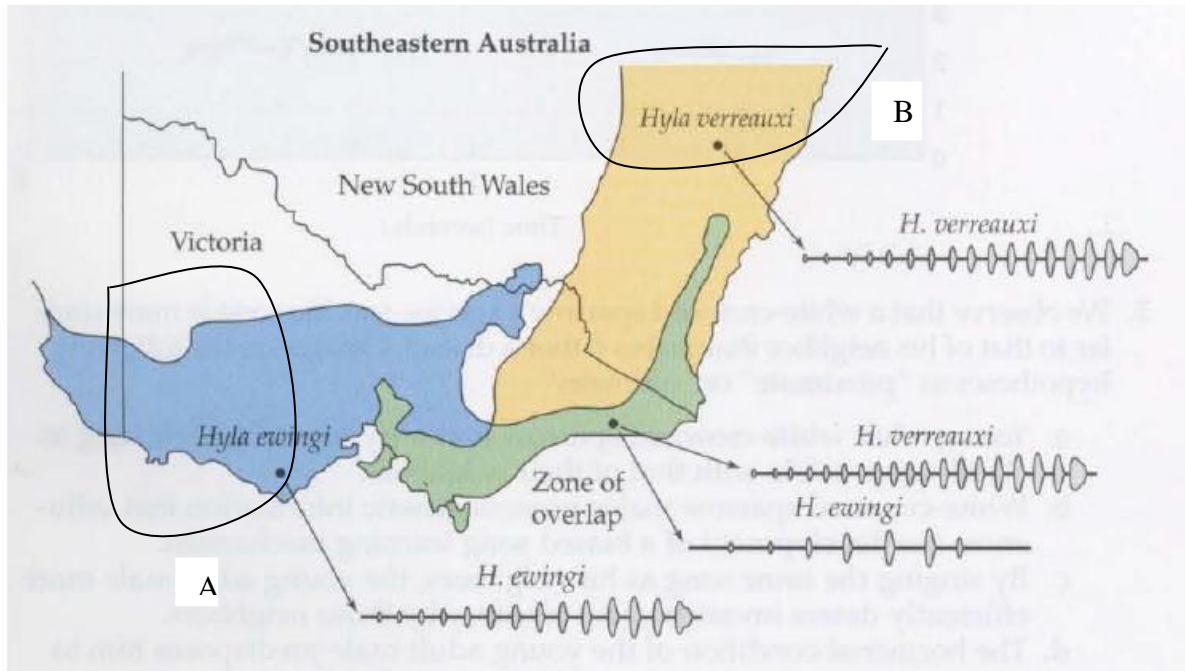
Analyse the following statements with reference to the data provided and indicate with a T or F whether each is true or false respectively.

a. The largely similar mating calls of the two species in their zones of exclusive distribution clearly indicate that the two species will hybridise with one another. _____

b. The distinct differences in the mating calls of the two species in the zone of distributional overlap, however, suggests that both the calls may have evolved distinctive patterns in this zone by parallel evolution. _____

c. The marked difference in the mating calls of *H. ewingi* between region A and region of overlap is due to 'Founder effect'. _____

d. In general, it is possible for two species from regions A and B to have never evolved reproductive isolation mechanisms. _____

52. (4 points) Breeding in birds is mostly of the non-cooperative type, in which the male and female rear the young ones. As they mature into adults, they leave the nest in search of a new nesting site. However, in cooperative breeding, individuals other than the genetic

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parents help raise the young. They are called "helpers". Very often these helpers are male offspring from the previous clutch. The average brood size of a pair with helpers has always been found to be larger than the one without helpers.

(A) For a population currently without co-operative breeding, analyse the following situations and mark whether each of them will favour or not favour co-operative breeding.

Indicate by putting tick marks (✔) in the appropriate boxes.

a. High rate of adult and juvenile survival.

b. Surplus of mature individuals relative to available territory.

c. A large difference in territory quality with some with very poor resources.

d. Female-biased skewed sex ratio in the population.

Situation	Favour	Not Favour
a.		
b.		
c.		
d.		

(B) In the co-operative breeding system, why would helpers help raise young ones which are not their own offspring? Mark each of the statements as true (T) or false (F).

a. This act will ensure the survival of the species. _____

b. It can increase probability of the future breeding in helpers. _____

c. It can increase production of non-descendent kin. _____

d. It can increase the helper's fecundity by the act of helping. _____

ECOLOGY (7 points)

53. (1+ [0.5 x 4] = 3 points) Succession can be viewed as a continuous process of colonization (immigration) and displacement (local extinction) of species at a site. The result is a continuous shift in species composition through time. The table below contains information on the plant species present in an old field community in over a 10 year period from 1988 to 1998. 'x' in the table indicates the presence of species while '0' indicates absence of species.

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One of the most common approaches to characterize the rate of change is to calculate the rate of species turnover during some time interval. This can be calculated by the following equation.

$$TO = (I + E)/(S_t + S_{t+1})$$

where, TO = Turnover rate between time t and t+1, I = Immigration rate (number of species colonizing per year) , E = extinction rate (number of species getting displaced per year) and S_t is the total number of species existing in the given year.

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Agropyron repens	x	0	0	0	0	0	0	0	0	0	0
Poa pratensis	x	x	x	0	0	0	0	0	0	0	0
Agrostic scabra	x	x	x	x	0	0	0	0	0	0	0
Ambrosia artemisifolia	0	x	x	x	x	x	x	x	x	x	x
Barteroa incana	0	x	x	x	x	x	x	x	x	x	x
Erigeron canadensis	0	x	x	x	x	x	x	x	x	0	0
Setaria lutescens	0	0	0	x	x	x	x	x	x	x	x
Aristida basiramea	0	0	0	x	x	x	x	x	x	0	0
Panicum oligosanthes	0	0	0	x	x	x	x	x	x	x	0
Rumex acetosella	0	0	0	x	x	x	x	x	x	x	x
Polygonum convolvalus	0	0	x	x	x	0	0	0	0	0	0
Hedeoma hispida	0	0	0	0	x	x	x	x	x	x	x
Digitariz ischaemum	0	0	0	0	0	0	x	x	x	x	x
Lepidium densiflorum	0	0	0	0	0	0	0	0	x	x	x
Solidago rigidu	0	0	0	0	0	0	0	0	0	x	x
Tragopogon dubius	0	0	0	0	0	0	0	0	0	x	x
Number of species	3	5	6	9	9	8	9	9	10	10	9
Immigration rate		3	1	4	1	0	1	0	1	2	0
Extinction rate		1	0	1	1	1	0	0	0	2	1
Species turnover rate		0.5									

(A) Calculate the species turnover rate (TO) for each year and write your answers in decimal form in the appropriate boxes in the table.

Note: The TO for 1989 has already been calculated and filled.

Analyze the data and answer the following questions.

(B) The lowest species diversity was found in the year _____.

(C) The highest rate of species turnover was found during the years_____ to ____.

(D) The highest species turnover occurred during the years_____ to _____.

(E) The lowest observed rates of species turnover is _____.

54. (2 points) The manner in which species are connected within a food web has implications for community structure and dynamics in addition to direct interactions between prey and predators. One of the ways in which the food webs of different communities differ is their degree of connectance, also known as 'connectance index'.

    Connectance is a way of describing how many possible links in a food web are present. They are simply the lines that link consumers and the consumed. A simple formula for calculating connectance index (C) is:
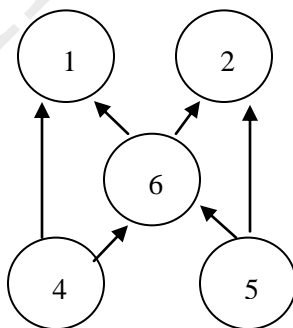
$$C = L/[\frac{S(S-1)}{2}]$$

    where L is the actual number of links in the food chain and S is the number of species in the food chain.

(A) What would be the number of possible links in a food web if the number of species was 5?

Answer: _____

(B) Now consider the food web represented below.

What is the connectance index for this food web? (Express the answer in decimal form.)

Answer: _____

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55. (2 points) To obtain a clear and systematic picture of mortality and survival within a population, ecologists use an approach involving the construction of life tables. The life table is an age-specific account of mortality. The life table of a Gypsy Moth population is represented below.

l_x represents the probability of the given stage surviving relative to the first stage.

q_x represents the rate of mortality for the given stage of life cycle.

| x	l_x	q_x
Eggs	1.000	0.300
Instars I-III	0.700	0.819
Instars IV-VII	0.127	0.582
Prepupae	0.053	0.038
Pupae	0.051	0.29
Adults	0.036	1.000

If the number of eggs were 450, what would be the number of pupae that **do not** survive to become adult Gypsy Moths?

Answer: _____

BIOSYSTEMATICS (8 points)

56. (4 points) Consider the two phylogenies given below. They are based on the evolutionary relationships between the various groups. Dots in the cladogram indicate common ancestors.

Evolutionary time scale

Evolutionary time scale
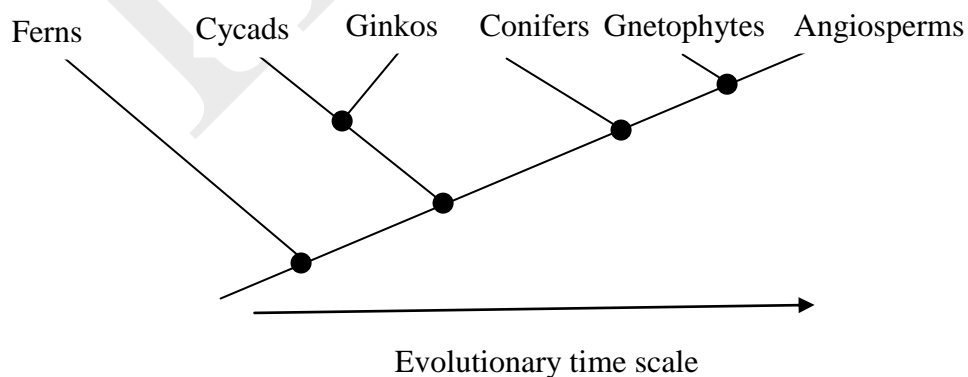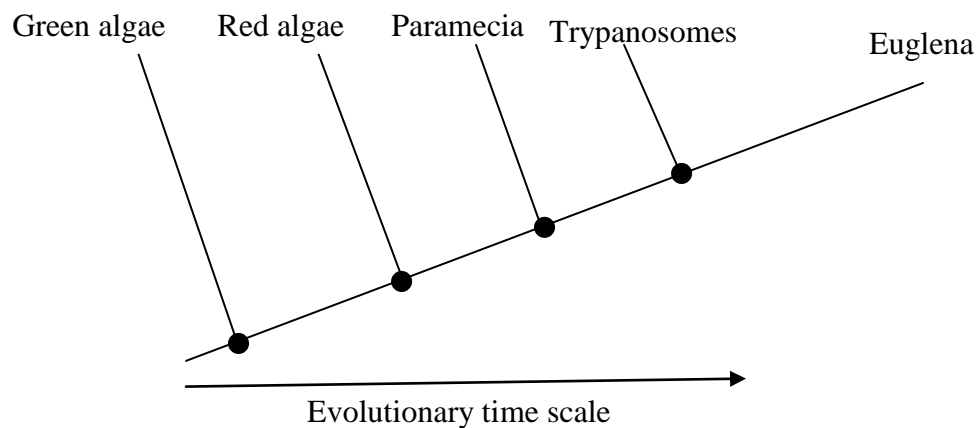
Match the correct description for each clade listed in the table and identify the type.

	Clade consisting of:	Description	Type
A	Cycads, Ginkos, Conifers and Gnetophytes		
B	Conifers, Gnetophytes and Angiosperms		
C	Paramecium, Trypanosome and Euglena		
D	Green algae, Red algae and Euglena		

Options for Description:

I. Members include all descendents of the most recent common ancestor.

II. Members include some of the descendents of most recent common ancestor.

III. Members of the clade do not share a recent common ancestor.

Options for Type:

(i) Monophyletic

(ii) Paraphyletic

(iii) Polyphyletic

57. (2 points) The genomes of four strains of *E. coli* (S1, S2, S3 and S4) have been sequenced. The percent differences in their genome sequences are shown in the matrix below.

	S1	S2	S3	S4
S1	0	6	8	10
S2	-	0	8	10
S3	-	-	0	10
S4	-	-	-	-

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Assuming maximum parsimony, construct a phylogenetic tree that correctly depicts the relationship between the four species and draw in the box given. Vertical lines should indicate the percent differences in the sequence between the species.

Answer:
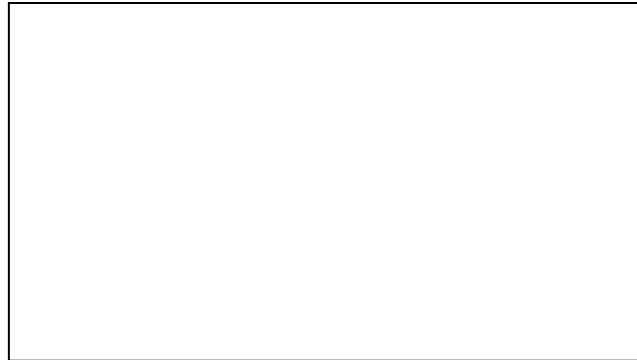
58. (2 points) A classification of plant kingdom based on evolution of various characters is shown below.
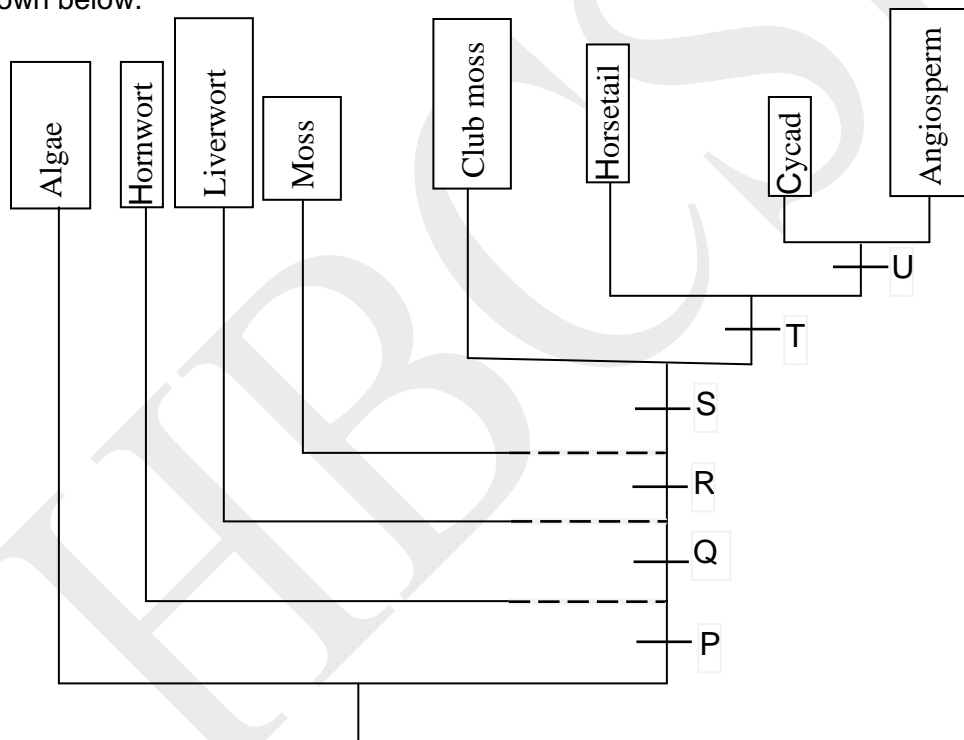
A few of these characters (I to IV) are listed below. For each of these characters, choose a single appropriate alphabet from the cladogram and fill in the blanks.

I. Wood: _____

II. Seed development: _____

III. Cuticle, protected embryo: _____

IV. Independent sporophyte: _____

********* **END OF SECTION B** *********